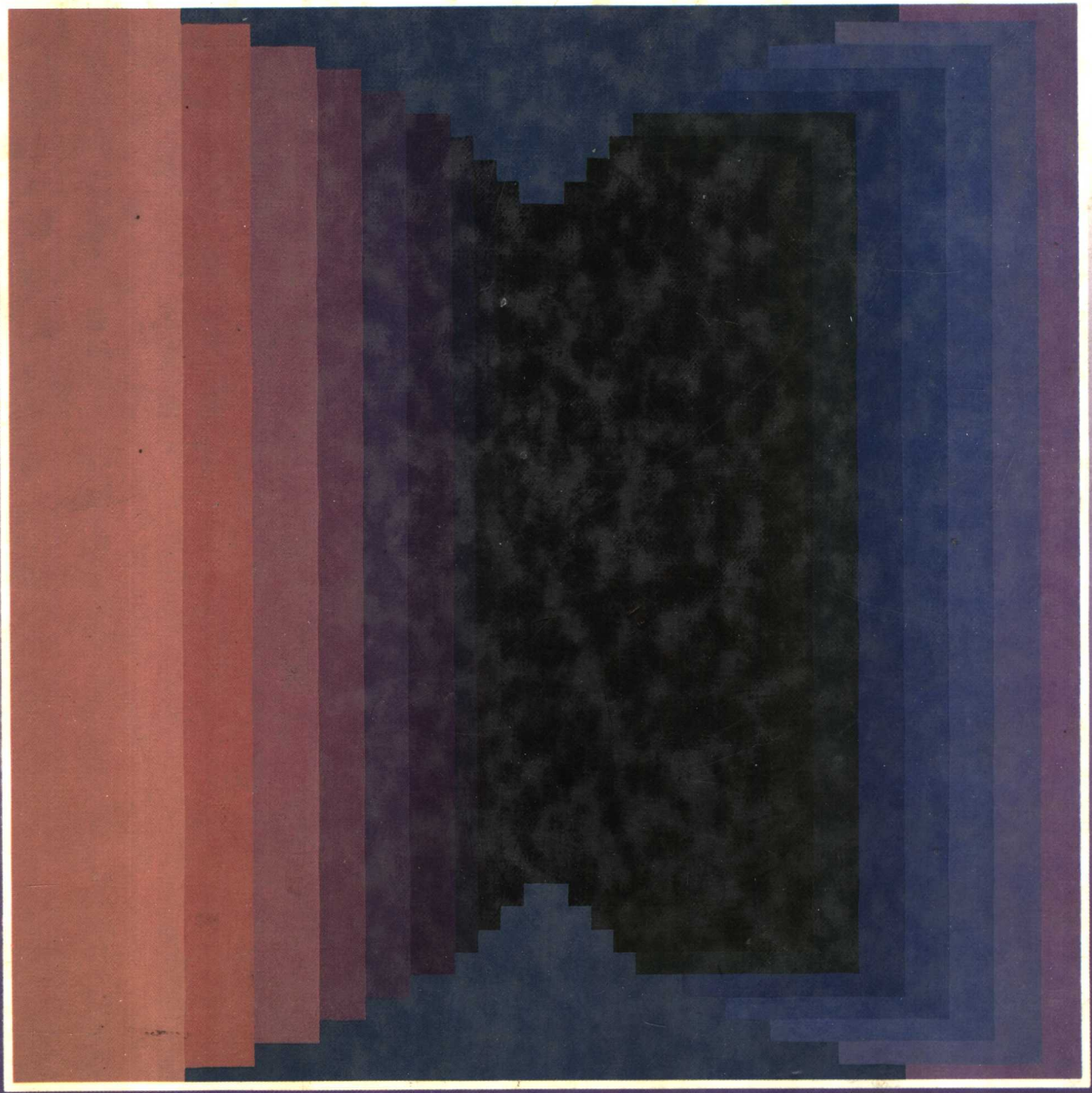
COLLEGE ALGEBRA

LOUIS LEITHOLD



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College Algebra

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To my son Marc
and his sons Justin and Matthew

THE COVER ARTIST

The drawing reproduced on the cover is by Allen Harrison, a painter living and working in Los Angeles. His art deals with multiple planes of color and surface considerations involving a reductive technique. Harrison builds up layers of paint and wet sands between each layer to leave smooth squares or color rectangles. As the planes overlap, edges emerge with varying degrees of visibility that divide the interiors of the planes. Often he will use transparent or translucent colors built up over a layer of opaque color to create a luminous surface. In a structural sense, he uses symmetrical compositions which are layered in such a way as to alter the appearance of symmetry.

Harrison is represented by Tortue Gallery, Santa Monica, and O.K. Harris Works of Art, New York City.

Preface

In a course titled "College Algebra" a student should gain an appreciation of mathematics as a logical science, and the subject matter should be expounded in such a way that it conforms to the experience and maturity of the freshman mathematics student. Furthermore, the course is rarely a terminal one in mathematics, and thus another of its purposes is to present the means to develop skills that will enable a person to study effectively more advanced courses. With these objectives in mind, I have attempted to reflect the consensus that mathematics should be meaningful, and I have made every effort to write a textbook that students can read advantageously on their own.

Chapter 1 I assume that the student has had courses in plane geometry and intermediate algebra, or the equivalent, and may need a review of some of the material but not a redevelopment. Consequently, the pace is quick for the algebra topics that appear in Chapter 1.

The sections in this chapter may be covered in detail, treated as a review, or omitted. If the chapter is omitted, I recommend that students read on their own Section 1.1 because the understanding of subsequent material requires a familiarity with facts about the set of real numbers and its subsets. The last section in the chapter introduces the set of complex numbers in preparation for their appearance later as solutions to some equations.

Chapter 2 The first four sections of Chapter 2, devoted to solving linear and quadratic equations in one variable, also constitute a review of Intermediate Algebra. In Section 2.2 a step-by-step method, with numerous examples, is given as a possible procedure for solving word problems. Because of the importance of inequalities in later work in mathematics, the last three sections of the chapter should be studied in detail. Polynomial and rational inequalities are solved by finding critical numbers and determining the sign of the polynomial or rational expression on intervals on the real number line. We use extensively tables summarizing the results and figures showing the intervals to obtain solution sets of inequalities.

Chapter 3 An introduction to analytic geometry is presented in Chapter 3. The topics appearing include the traditional material on lines, circles, and parabolas. Graphs of these curves are discussed here so that they are available prior to the treatment of functions in Chapter 4. Supplementary Section 2.6 gives a brief discussion of the ellipse, the hyperbola, and conic sections.

Chapter 4 Chapter 4 is especially significant because the notion of a function is crucial for the study of more-advanced mathematics and is used as a unifying concept throughout much of the remainder of the book. I introduce a function as a correspondence from one set of real numbers to another but I define it as a set of ordered pairs to make its meaning precise. This formal definition of a function leads to the definition of the graph of a function as a set of points in a plane. Because of the importance of these two definitions there are numerous examples, illustrations, and exercises in Section 4.1 pertaining to them.

In Section 4.3 the mathematical models of functions are those encountered in later work and are designed to prepare the student to express a practical situation in terms of a functional relationship. The discussion of quadratic functions in Section 4.4 utilizes graphs of parabola studied in Chapter 3. In Section 4.5 the treatment of graphs of polynomial functions is as complete as possible without using calculus. Just as thorough a coverage of graphs of rational functions occurs in Section 4.6. The inverse of a function is defined in Section 4.7 in preparation for its application in Chapter 5.

Chapter 5 The emphasis in Chapter 5 is on the properties of exponential and logarithmic functions. I introduce the number e in Section 5.1 by considering interest on an investment at a rate compounded continuously and follow this discussion by an intuitive demonstration of how e can be defined in calculus: the number that the expression $\left(1+\frac{1}{x}\right)^x$ approaches as x increases without bound.

I discuss exponential functions in Section 5.2 and define a logarithmic function in Section 5.3 as the inverse of an exponential function. Properties of logarithmic functions appear in Section 5.4, and Section 5.5 is devoted to exponential and logarithmic equations. Throughout the chapter there are applications in all of the sciences. These applications involve exponential growth and decay as well as bounded growth.

Chapter 6 A straightforward coverage of systems of equations and inequalities and matrices appears in Chapter 6. In Section 6.1 systems of two linear equations are discussed, and systems involving three linear equations are treated in Section 6.2. I present systems involving quadratic equations in

two variables in Section 6.3 and systems of linear inequalities along with their use in linear programming in Section 6.4.

We solve systems of linear equations by the Gaussian reduction method involving matrices in Section 6.5 and by determinants and Cramer's rule in Section 6.6. There are two supplementary sections, 6.7 and 6.8, involving properties of matrices and solutions of linear systems by matrix inverses.

Chapter 7 Chapter 7 pertains to polynomial functions and polynomial equations. Synthetic division, discussed in Section 7.1, is a computational tool used in Section 7.2 to find rational zeros of polynomial equations. The discussion of roots of polynomial equations, begun in Section 7.2, is continued in Section 7.3 where I develop a systematic method to find the exact or approximate value of all real roots. The treatment of zeros of polynomial functions is completed in Section 7.4 where we determine complex zeros.

In Section 7.4 I state and prove the theorem used in Supplementary Section 7.5 when working with partial fractions: a polynomial with real coefficients can be expressed as a product of linear or quadratic polynomials with real coefficients.

Chapter 8 There is a variety of algebra topics in Chapter 8. Sequences and series play an important part in later work in mathematics, and in Section 8.1 there is a brief introduction to them based on the function concept. The first section also includes a discussion of the sigma notation, which is applied to write a summation. Section 8.2 is devoted to mathematical induction, a technique used to prove certain theorems involving positive integers. I cover arithmetic sequences and series in Section 8.3, geometric sequences and series in Section 8.4, and infinite geometric series in Section 8.5.

Counting, permutations, and combinations are applied to everyday-life situations in Section 8.6, and in Section 8.7 counting forms a basis for an introduction to the theory of probability. In the discussion of the binomial theorem in Section 8.8, I treat the binomial coefficients as combinations and utilize this concept in the proof of the binomial theorem.

Flexibility Because there is a diversity of opinion regarding the content of a text in college algebra, there are more topics in this book than can be covered in a standard course of three semester hours. The instructor should choose the material that is appropriate for his or her class. As mentioned above, Chapter 1 may be omitted. Chapters 2 through 6 should be covered in most courses with the stipulation that any supplementary sections can be included or omitted without affecting the understanding of subsequent subject matter. Chapters 7 and 8 are self-contained, and either or both can be deleted from a short course.

Examples and Illustrations

Examples and illustrations are included in each section. The examples were carefully selected to prepare students for the exercises and should be used as models for their solutions. An illustration serves to demonstrate a particular concept, definition, or theorem; it is a prototype of the idea being presented.

Exercises

There are over 3600 exercises, appearing either at the end of a section or as review exercises following the last section of a chapter. These exercises are varied in scope and have been graded in difficulty, ranging from elementary to very challenging. They stress the computational, theoretical, and applied aspects of the subject. The applications encompass a multitude of fields including physics, chemistry, engineering, astronomy, navigation, biology, medicine, business, economics, sociology, psychology, and statistics.

The answers to the odd-numbered exercises are given in the back of the book, and the answers to the even-numbered ones are available in a separate booklet.

Calculators and Tables

I recommend that students studying this text own a scientific calculator containing keys for exponential and logarithmic functions. In Chapter 5 there are examples, illustrations, and exercises involving elementary computations with such a calculator. The speed and accuracy afforded by a calculator makes their use preferable to that of tables. Nevertheless there are tables in the back of the book for exponential functions and natural and common logarithms.

Pacific Palisades, California L.L.

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SUPPLEMENTS

For the Instructor

Complete Solutions Manual Containing the worked-out solutions for all the exercises in the text.

Even Numbered Answer Book Containing the answers for all the even-numbered exercises in the text.

For the Student

Student's Solution Manual Containing worked-out solutions for every third exercise in the text.

Computerized Testing Systems

AWTest Based on the learning objectives of the text, this easy to use, algorithm-based system allows the instructor to generate tests, quizzes, or remedial exercises. AWTest is available for the IBM-PC*. Departmental software free upon adoption.

AWTest Edit This is a computerized test bank containing over 2500 multiple-choice test items for the IBM-PC*. The program allows the instructor to edit existing test items and/or enter new items. Also tests may be created with both multiple-choice and open-ended questions. Departmental software free upon adoption.

Printed Test Bank At least three alternate tests per chapter are included in this valuable supplement. Instructors can use these items as actual tests or as a reference for creating tests with or without the computer.

Transparencies This package of acetates includes a selection of key definitions, figures, proofs, formulas, tables, and applications that appear in the text.

Computer Supplements for the Instructor and the Student

Master Grapher and 3D Graphing Software by Bert Waits and Frank Demana (Ohio State University). These two interactive, utilities packages are available for the IBM-PC*, MacIntosh*, and Apple II series computers.

Master Grapher enables the user to graph and manipulate functions in two dimensions. This program features the ability to change function parameters, rotate axes, overlay one graph with another, and perform a variety of transformations.

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